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Enhancing Traffic Management with a Digital Twin: Optimizing Signal Timing for FIFA Events

Title Enhancing Traffic Management with a Digital Twin: Optimizing Signal Timing for FIFA Events at AT&T Stadium in Arlington, Texas		**Report Date** May 2025
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Abstract

Like many other cities, the City of Arlington (COA), Texas, actively monitors traffic through its Traffic Management Center (TMC) using a network of cameras and real-time data feeds. While these efforts help manage traffic flow, current practices rely on reactive measures—adjustments are only made after congestion or delays are observed. This traditional approach means that traffic issues must first occur before corrective actions can be taken. With advancements in technology, a Digital Twin approach offers a proactive solution. A Digital Twin replicates roadway infrastructure and signal timing in a virtual environment, enabling the simulation of future traffic conditions before they occur. For special planned events, such as football matches, COA typically adjusts signal timing before and after the event based on real-time observations from live cameras. While this method has been effective, further improvements can be made by anticipating and mitigating congestion in advance. To bridge this gap, the student team at the University of Texas at Arlington (UTA) is developing a Digital Twin of the roadway network surrounding the stadium. This model will simulate future scenarios, such as increased traffic volumes during FIFA events, to identify potential bottlenecks and optimize signal timing adjustments. The focus of this case study is on pre- and post-event traffic, where a surge in demand can lead to significant congestion, particularly at key intersections. By leveraging the Digital Twin, the team aims to analyze traffic flow patterns, pinpoint intersections experiencing the highest delays, and evaluate signal timing modifications to alleviate congestion. Through these simulations, we seek to implement proactive strategies that minimize delays, improve traffic efficiency, and enhance the city's overall traffic management capabilities during the FIFA event.

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List of Acronyms

- **ACTION** Advanced Computing in Transportation, Information, Operations, and Networks
- **ATSPM** Automated Traffic Signal Performance Measures
- **COA** City of Arlington
- **CV** Connected Vehicle
- **ITE** Institute of Transportation Engineers
- **ITS** Intelligent Transportation Systems
- **LOS** Level of Service
- **NCTCOG** North Central Texas Council of Governments
- **OSM** OpenStreetMap
- **ROI** Region of interest
- **MOE** Measure of Effectiveness
- **TMC** Transportation Management Center
- **TSP** Transit Signal Priority
- **TxDOT** Texas Department of Transportation
- **UTA** University of Texas at Arlington
- **VHD** Vehicle Hours of Delay
- **FYA** Flashing Yellow Arrow

1. INTRODUCTION

Transportation is a critical component of a country's economy, facilitating the movement of goods and services and supporting economic growth. In a rapidly growing city like Arlington, it is especially important for city officials to manage traffic delays and ensure smooth network operations. Traffic delays are not only inconvenient but also costly estimated at approximately $1.50 per minute for both cars and trucks (*1*). These costs become particularly prominent during large-scale events that draw substantial traffic to concentrated areas, often resulting in excessive delays. A key area of focus in Arlington is its Entertainment District, which includes major attractions such as AT&T Stadium (home of the Dallas Cowboys and host to concerts and major events), Six Flags Over Texas, Hurricane Harbor, and Globe Life Field. Collectively, these venues attract nearly one million trips annually, creating significant traffic demand and congestion challenges (*2*). Figure 1 illustrates the layout of the Arlington Entertainment District and its major destinations, highlighting the concentration of traffic activity in this area.

To address these challenges, city, state, and municipal agencies have undertaken special efforts to manage event-related traffic surges. For example, the Dallas-Fort Worth Regional Transportation Council under the North Central Texas Council of Governments (NCTCOG) has partnered with the City of Arlington to prepare for the upcoming 2026 FIFA World Cup. Managing traffic during such high-demand events is a core focus of the Transportation Systems Management and Operations (TSMO) program led by the Texas Department of Transportation (TxDOT). As part of this initiative, a team led by students from the University of Texas at Arlington (UTA) will explore innovative traffic operations strategies by leveraging a microsimulation tool enhanced by big data and integrating it with a real-time external controller.

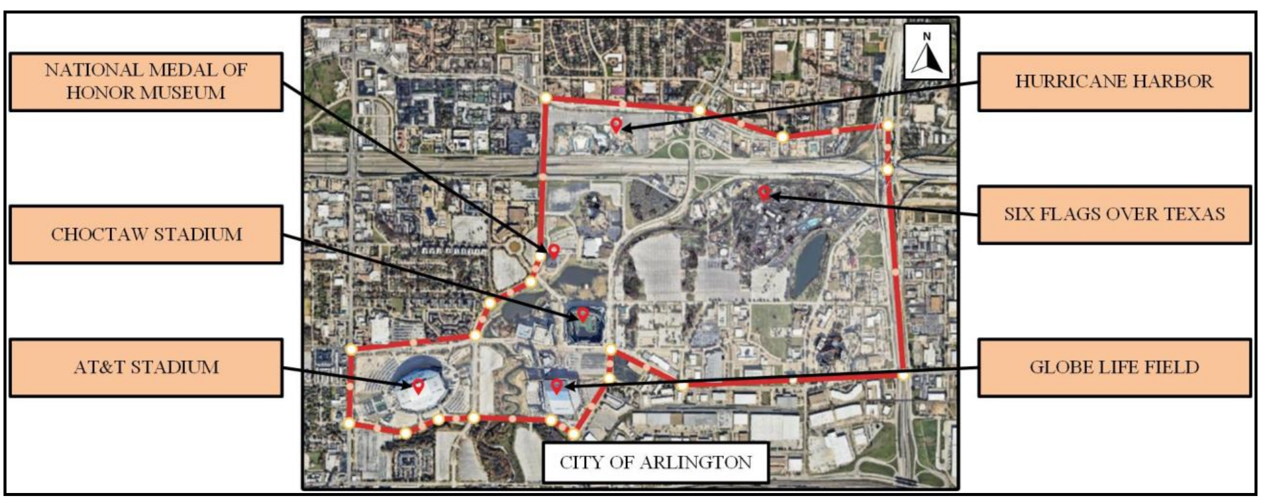

Figure 1: Arlington Entertainment District with Major Event Venues.

2. DESCRIPTION OF PROBLEM

In 2026, the FIFA World Cup will be jointly hosted by Canada, Mexico, and the United States. As one of the largest global sporting events, the World Cup draws over a billion viewers, making it imperative for host countries to coordinate closely with local city planners to ensure all logistical elements are in place well before the event begins. Among the selected venues, the AT&T Stadium, located in the City of Arlington (COA), is set to host nine matches, including the semi-final (*3*). The upcoming tournament is expected to be even larger than previous editions, featuring 48 teams instead of 24. Hosting such a high-profile event presents significant challenges. As the host city, Arlington bears the responsibility of managing traffic operations and mobility logistics. This includes addressing critical concerns around safety, security, and potential delays. What makes this even more complex is that Arlington currently lacks a mass transit system, such as rail or bus service. Therefore, the city must explore innovative strategies to enhance safety and reduce delays, while ensuring that these measures do not disrupt the daily routines of residents. Proactive planning will be essential to successfully accommodate the influx of visitors and maintain seamless urban mobility throughout the event.

Over the past year, substantial progress has been made in advancing transportation strategies to develop new performance measures focused on minimizing delays and enhancing traffic flow. Like many growing cities COA, actively monitors traffic through its Traffic Management Center (TMC), utilizing a network of live cameras and real-time data feeds. COA employs a unique signal timing strategy known as "inbound and outbound" timing, which has proven effective during major events, including Dallas Cowboys games and concerts at the stadium, such as Taylor Swift's. Prior to events, signal timings are adjusted to favor inbound traffic, increasing roadway capacity by using longer cycle lengths. Reversible lanes near the stadium are also utilized to accommodate directional traffic flow, with lanes favoring inbound traffic before events and outbound traffic afterward. While these tools support traffic management, the current approach largely relies on response-based measures, which require continuous manual oversight and adjustments only after congestion is detected. TMC operators monitor live feeds and make signal timing changes in response to observed delays. This means congestion must first occur before any corrective actions are taken, and even then, there is a lag before traffic conditions stabilize. While this approach has been sufficient in the past, the 2026 FIFA World Cup presents an unprecedented challenge. Historical data suggests that host cities experience up to a 100% increase in overall vehicle volume, with localized surges reaching 155% near stadium areas, significantly higher than any event previously hosted in the COA (*4*). Recent insights from StreetLight's analysis using connected vehicle (CV) data further illustrate the magnitude of such impacts. For example, during Taylor Swift's 2018 Eras Tour - one of the most attended concert tours in U.S. history - vehicle hours of delay (VHD) more than doubled on roadways surrounding concert venues (*4*). Across all stadiums studied, VHD increased by an average of 277% compared to typical conditions. Notably, AT&T Stadium in Arlington, which hosted one of these concerts, experienced a staggering 515% increase in VHD as shown in Figure 2.

Given the anticipated demand, relying solely on reactive traffic management may not be sufficient, highlighting the need for a more proactive, data-driven strategy. In response, Arlington is actively leveraging technology to address the challenges of high demand during planned special events and enhance overall road safety.

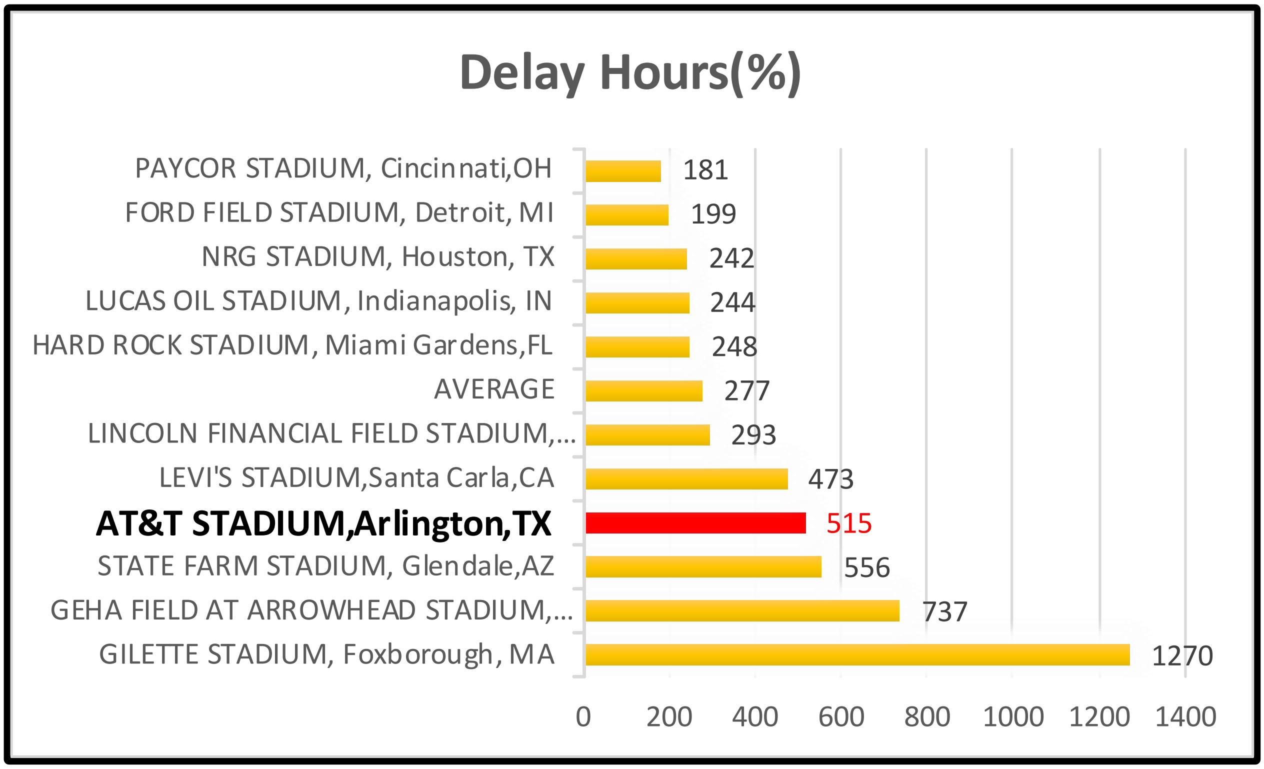

Figure 2: Percent Change in Vehicle Hours of Delay During Major Events (e.g., Taylor Swift Eras Tour) Compared to Normal Conditions.

3. DESCRIPTION OF SOLUTION

The COA is interested in evaluating whether the infrastructure surrounding AT&T Stadium can accommodate the surge in traffic expected during the FIFA World Cup. To support this effort, Team Mavericks from the UTA is developing a Digital Twin of the roadway corridor adjacent to the stadium using PTV VISSIM, a state-of-the-art traffic simulation tool. A Digital Twin is a virtual representation of a physical object, system, or process that continuously updates using real-time data to replicate real-world behavior, performance, and conditions.

The primary objective is to simulate traffic delays that may occur during the 2026 FIFA World Cup by incorporating forecasted travel demand associated with the event. Delays within a roadway network can result from multiple factors, including human behavior, roadway geometry (e.g., limited sight distance), or suboptimal signal timing. The COA currently uses standardized signal timing patterns coordinated throughout the day, including special plans activated during large-scale events. These plans typically involve increased cycle lengths to favor inbound traffic heading toward the stadium. While such signal plans are usually evaluated using static software tools like VISTRO or SYNCHRO, those tools often provide only generalized performance insights. In contrast, the use of a Digital Twin model enhanced by CV data and real-time control logic allows for a far more dynamic and realistic simulation.

The student team is modeling a 7-intersection corridor along Collins Street, stretching from I-30 to Abram Street. These seven specific intersections were selected due to their proximity to the stadium and their role in connecting two major freeway systems - Interstate I-30 and TX-360 - which contribute to higher traffic demand in the area. This corridor was constructed within VISSIM using base infrastructure data such as lane configurations and turn channelization, sourced from Google Earth imagery. However, a model is only as accurate as the data it runs on. To ensure realism, the team incorporated a wide range of data:

- Speed and acceleration profiles from CV data
- Turning movement and volume counts collected manually during a peak hour on Monday by the student team and nine volunteers from UTA-ITE
- Signal timing plans and detector layouts provided by the City of Arlington

The model was calibrated following FHWA guidelines to ensure alignment with observed ground truth values for volume, speed, and travel time (*5*). A critical feature of the simulation is its integration with a live signal controller interface - MaxTime by Q-Free. While VISSIM offers a built-in RBC controller, it lacks the full functionality of real-world controllers. MaxTime provides a free, web-based controller interface that more accurately replicates COA's actual signal operations, making it both a technically robust and cost-effective solution.

Signal plans are complex; a typical intersection may have up to 16 sequences and over 60 timing patterns. Rather than testing all combinations, the team focused on the evening peak hour (4:45 PM–5:45 PM) using the actual pattern active during that timeframe. Once the model was calibrated and validated for baseline conditions, it was ready for scenario testing.

In preparation for high-demand events like FIFA, the team incorporated COA's inbound signal timing strategies, adding logic that activates special event patterns once a threshold vehicle volume is reached. Through Measures of Effectiveness (MOEs) such as travel time, level of service (LOS), and delay, the model is used to evaluate whether current infrastructure and timing plans are sufficient. If not, alternative signal plans can be proposed. This Digital Twin enables COA to simulate anticipated traffic conditions, identify potential congestion points, and proactively test signal timing adjustments even before the event takes place. The overarching goal is to manage pre-event traffic surges effectively, particularly at critical intersections, and support a data-driven, resilient traffic management strategy for one of the world's largest sporting events.

3.1 Stakeholders

Identifying and understanding the key stakeholders is a critical step in ensuring the success of any project. Stakeholders provide valuable resources, data, expertise, and decision-making support that shape the direction and impact of the initiative. In this project, the following agencies, groups, and organizations play vital roles and are directly involved or affected:

- **University of Texas at Arlington:** UTA provides high-performance computing resources equipped with GPU capabilities, including the AMD Radeon Pro WX 2100, which are essential for processing CV datasets and running VISSIM simulations. These resources support the development and operation of the digital twin framework.

- **City of Arlington:** The City of Arlington is the lead partnering agency in this project. COA identifies areas of interest, including specific intersections and corridors for analysis. Their guidance is critical in selecting the case study location and aligning the project goals with the city's transportation priorities.
- **UTA ITE/ITS Student Chapter**: Students from the UTA ITE/ITS Chapter are responsible for developing the simulation tools and creating detailed guidelines and memos for setting up the digital twin framework. Additional members assist with data collection efforts, including vehicle and turning movement counts.
- **North Central Texas Council of Governments:** NCTCOG supports the project by providing valuable regional data, such as forecasted travel demand and traffic volumes expected during Future planned events. This information is crucial for accurate scenario modeling.
- **Transportation Management Center:** The COA TMC provides real-world signal timing plans and detector layouts for each intersection. This data is essential for accurately replicating traffic conditions within the simulation environment.
- **Advanced Computing in Transportation, Information, Operation, and Networks (ACTION Lab):** The ACTION Lab at UTA analyzes all results obtained from the digital twin framework. Based on city-defined thresholds, key intersections within the case study area are evaluated, and recommendations for signal retiming are provided. The lab also offers hands-on training to COA and TMC personnel on how to develop and calibrate the digital twin framework.
- **Other Stakeholders (e.g., TXDOT, other cities):** Additional stakeholders support the deployment and maintenance of the digital twin framework. They assist with broader network integration, model calibration, training programs, and expansion efforts to other jurisdictions or study areas.

4. CON-OPS SOLUTION

4.1 High-Level Functional Architecture

The functional architecture of this system includes a computer capable of running PTV VISSIM simulations. For effective integration of an external controller, a compatible version of VISSIM is required: VISSIM 11 or 2020 and above. This project uses VISSIM 2025 under a PTV Group - AME Training license. The software supports a wide range of features such as vehicle behavior modeling, railroad simulation, transit signal priority, preemption, pedestrian movements, and even ferry and ship operations. However, for this project, the vehicle fleet is limited to cars and heavy goods vehicles. A core component of the system is CV data, which is crucial for model calibration. Due to the massive volume of CV data, which can contain millions of data points in a single day across the entire Dallas-Fort Worth region, map-matching algorithms are essential. Based on the method from Khadka et al., CV data is filtered to focus on the Collins Street corridor (*6*). To extract relevant data, a Region of Interest (ROI) polygon is created using GIS tools in KML format. The filtering process uses distance and heading thresholds in relation to roadway links obtained from

OpenStreetMap (OSM). This ensures that only the required speed and acceleration profiles for Collins Street are used in the model. Model calibration follows FHWA guidelines, as detailed in Table 1, Section 8 (Appendix). Once calibrated, the model integrates a Q-Free MaxTime controller as an external signal controller. Signal timing plans are carefully reviewed and implemented across all intersections using the MaxTime interface. To enhance visual realism, 3D elements such as trees, buildings, infrastructure, and the stadium are incorporated. Post-simulation, LOS for each intersection is calculated and stored in a database. This data is analyzed against performance thresholds set by the city to determine whether intersections operate efficiently. If performance falls short, signal timings are adjusted, and the simulation is rerun to assess improvements. The complete functional architecture is illustrated in Figure 3.

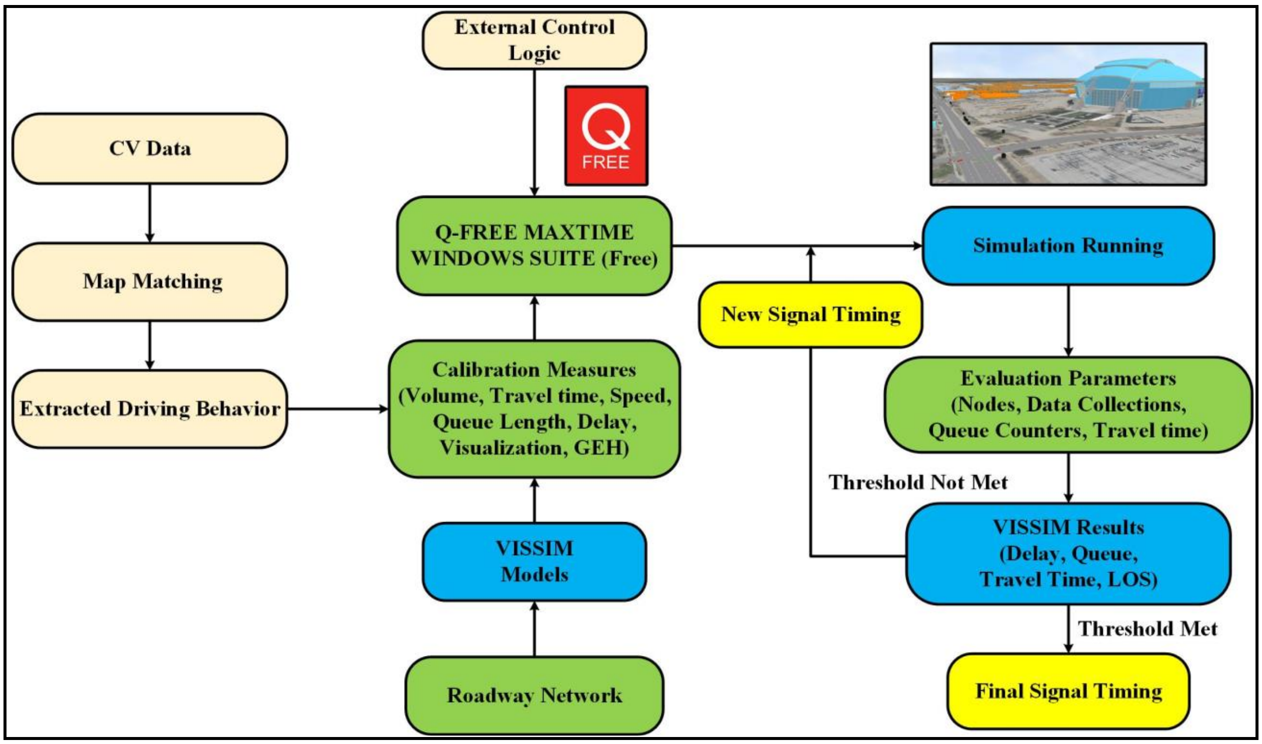

Figure 3: High-Level Functional Architecture

4.2 High-Level Physical Architecture

The high-level physical architecture comprises several critical components that enable the implementation and operation of the Digital Twin. These include pre-existing signal controllers, detection layouts, a high-performance computing system, and simulation software capable of integrating with external controllers. The primary objective of the simulation is to run the Digital Twin across multiple traffic scenarios with high computational efficiency. To achieve this, the team deployed PTV VISSIM on a computer equipped with an AMD Radeon Pro WX 2100 GPU, which accelerates the simulation to run up to five times faster than real time, significantly reducing both processing time and computational cost. A high-performance GPU is essential not only for running the simulation efficiently but also for executing the map-matching algorithm, which utilizes multithreading and parallel processing to handle large volumes of CV data. This allows the team to filter CV data to the ROI with precision and speed. The simulation setup also replicates the real-world detector layout. Depending on field data, either loop-based detectors or video detection systems are modeled, and corresponding detector zones are accurately placed within VISSIM. Additionally, to enhance realism and improve stakeholder understanding, 3D models of road infrastructure, buildings, trees, and the stadium were imported from external sources. To analyze the simulation results and evaluate MOEs such as delay and LOS, visualization tools like Microsoft Excel and Q-Free Visualization Suite are used. The complete high-level physical architecture of the system is illustrated in Figure 4.

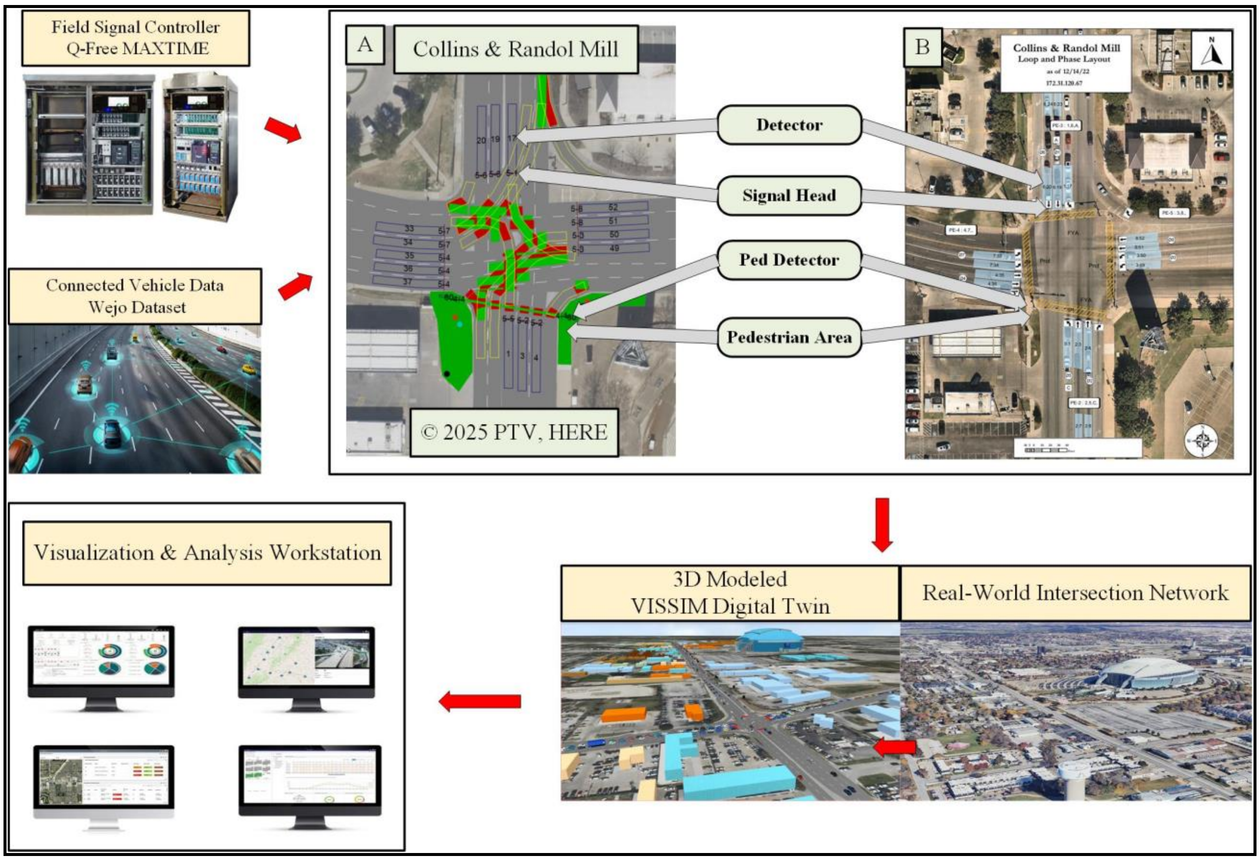

Figure 4: High-Level Physical Architecture

4.3 High-Level Enterprise Architecture

The high-level enterprise architecture is structured around four core components: business architecture, technology architecture, data architecture, and application architecture. These components guide the collaboration between key stakeholders - city agencies, the UTA student development team, and the end users - in supporting the development of a Digital Twin for the corridor near AT&T Stadium. Each component plays a specific role and involves distinct responsibilities, as illustrated in Figure 4. The COA plays a central role by providing critical infrastructure data, signal timing plans, and operational insights based on existing traffic management practices. Based on this input, the student team from the UTA is responsible for developing the Digital Twin simulation model. This model allows COA to test whether its pre-programmed signal timing strategies can effectively handle the forecasted increase in travel demand during the event. The end users are ultimately the traveling public, who stand to benefit from reduced delays, improved traffic flow, enhanced safety, and potentially lower emissions, making the system both efficient and environmentally responsible. All project data is managed locally, ensuring data security and privacy, with access provided upon appropriate request and approval.

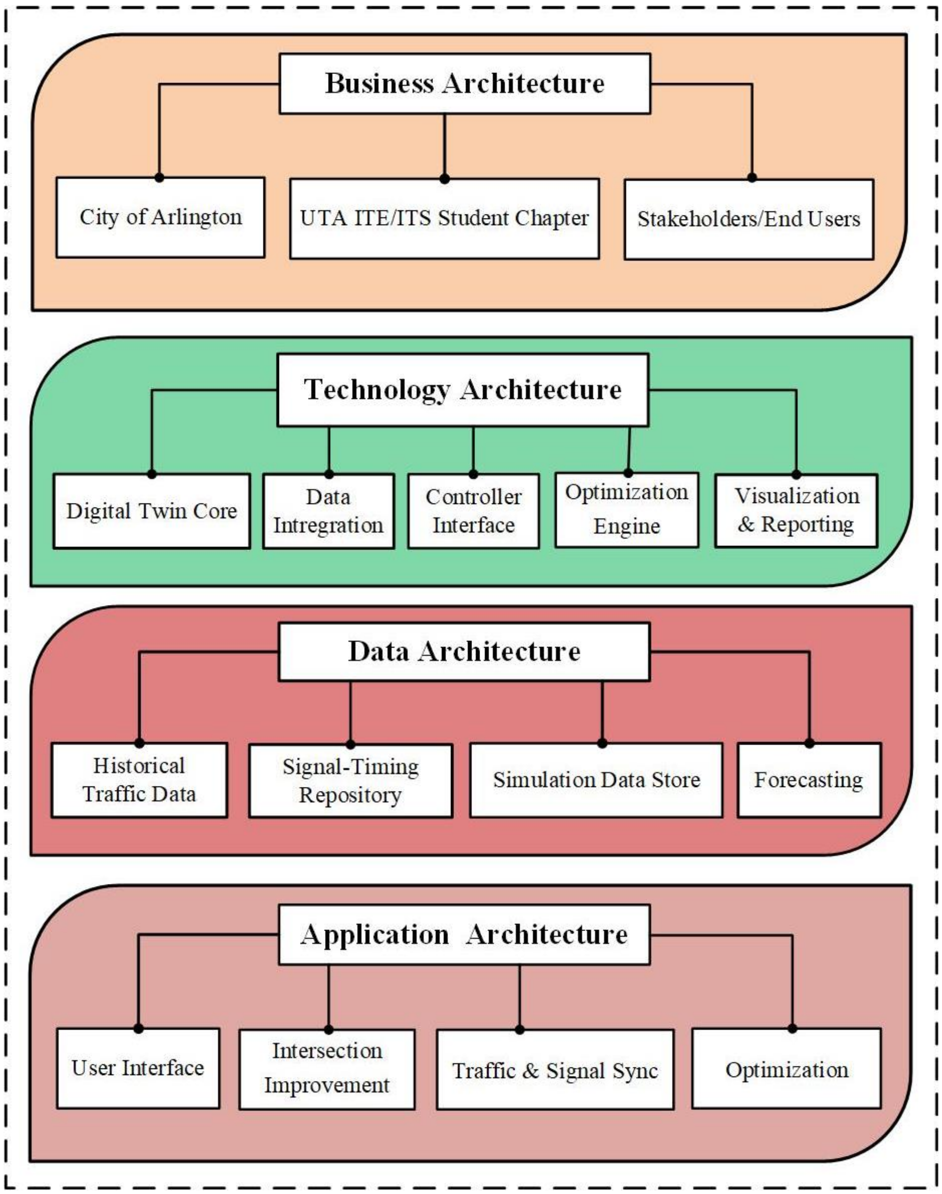

Figure 5: High-Level Enterprise Architecture

5. ANTICIPATED IMPACTS

This framework integrates CV data, simulation tools, and external controllers to improve traffic operations by minimizing delays under future scenarios. It enables the COA to proactively assess and refine signal timing plans in advance of special planned events. Although initially designed for such events, the framework is versatile and can also be applied to other use cases, including future development planning, general traffic management, and evaluating corridor performance for complex mass transit scenarios. This effort aligns with TSMO strategies, emphasizing the integration of technology to build an intelligent transportation system (ITS). While the primary goal is to reduce intersection delays and enhance traffic flow during major events, the framework also offers broader direct and indirect benefits.

5.1 Mobility Benefits

The primary objective of this project is to reduce delays at intersections, which is a direct and measurable benefit. Through simulation, various measures such as LOS can be used to evaluate signal timing plans in advance, helping the city select the most effective strategies. The tool can also support the evaluation of pedestrian evacuation plans. Although pedestrian design was not included in the current framework due to limited resources, the simulation has the capability to incorporate such features. This allows for scenario testing to better understand both vehicle and pedestrian queuing and improve overall evacuation planning.

In addition to signal timing optimization and evacuation planning, the simulation tool also supports analysis of signal preemption and transit signal priority (TSP). These features are critical for planners, as preemption enables safe and efficient movement for emergency vehicles, while TSP helps improve travel time and reliability for mass transit. Although the City of Arlington currently lacks a formal mass transit system, the tool allows the city to explore and evaluate the potential impacts of introducing services such as buses or trains. This makes the simulation a valuable asset for future transportation planning and strategic decision-making.

5.2 Operational Cost Benefits

Performing a signal retiming project can be costly for cities and municipalities. Beyond the upfront expenses, the cost is recurring, as each retiming effort requires starting the process from scratch. In contrast, developing a simulation tool supported by data is a more cost-effective approach for planning agencies, as it eliminates recurring costs. Once the simulation is built, a single planner can manage multiple intersections efficiently. Additionally, numerous resources and guidelines provided by DOTs help planners calibrate models quickly, reducing setup time and expenses. This approach also helps stabilize operational and maintenance costs over time.

5.3 Safety Benefits

Safety may not be the primary focus of this project, but it is certainly an important indirect benefit. When developing signal timing plans, several safety-related factors are considered, such as reducing the number of vehicles stops and minimizing conflict points. A good example is the use of the flashing yellow arrow (FYA) for left turns. While FYA can increase capacity for turning vehicles, it also introduces potential risks for concurrent pedestrian movements due to possible conflicts. By following FHWA guidelines and using the simulation tool, such risks can be identified and addressed early in the planning process, helping to improve overall intersection safety.

5.4 Environmental Benefits

Any development project should consider its environmental impact. Advancing technology should not come at the cost of environmental degradation. This project, while primarily focused on improving traffic operations, also offers indirect environmental benefits. Vehicle emissions are a major contributor to air pollution, and a significant portion of these emissions result from frequent stop-and-go movements (*7*). By minimizing delays at intersections through optimized signal timing, vehicles can move more smoothly, especially in coordinated systems. This reduction in stops and delays leads to lower CO2 emissions, supporting cleaner air and contributing to more sustainable urban development.

5.5 Economic Benefits

Overall, this framework offers a direct economic benefit by targeting one of the most significant challenges in traffic operations, which is reducing delays. As previously mentioned, delays can cost approximately $1.50 per minute, meaning every additional minute of vehicle delay translates to economic losses for taxpayers. By using this microsimulation framework, the COA can proactively assess and optimize intersections across the network, ultimately reducing delays and improving economic efficiency.

The main limitation of the framework lies in its complexity. Calibration requires a detailed and time-consuming process, and the simulation's accuracy depends heavily on the availability and quality of data. A digital twin is only effective when it is supported by robust and comprehensive data inputs. This data dependency may pose a challenge to implementation and scalability.

Nevertheless, from a broader perspective, COA can leverage this framework beyond delay reduction. It can also be applied to more complex scenarios such as railroad preemption and transit signal priority. Building on prior research conducted by the ACTION Lab in the same case study region, this framework can be integrated with visualization tools like Automated Traffic Signal Performance Measures (ATSPM) to generate clear, planner-friendly outputs that support informed decision-making.

6. ACKNOWLEDGEMENT

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8. APPENDIX

After constructing the roadway network, the team followed FHWA guidelines to calibrate the model. The specific thresholds for each calibration measure are outlined in Table 1.

Table 1: Calibration Guidelines from FHWA

Calibration Measures	Tools	Calibration Goal
Traffic Volume	Node Analysis	Within 100 vph for volume less than 700 vph
		Within 15 vph for volume between 700 vph and 2700 vph
		Within 400 vph for volume greater than 2700 vph
		Sum of link volumes to have GEH statistic value of 5 or lower.
Travel Time	Travel Time Measurement	For travel times < 7 min, calibrated time must be ±1 min of actual
		For travel times >= 7 min, calibrated time must in a range of 15% compared to actual travel time.
Speed	Data Collection Point	Simulated Average Speed to be within ±10 mph of actual measured speed.
Visualization	Individual	Check for bottlenecks and unusual turns

All calibration parameters were thoroughly evaluated. For any measures that initially did not meet the required thresholds, fine-tuning was carried out until all calibration standards were satisfied. Although the calibration process was conducted for all intersections, only detail of one intersection is presented here for demonstration purposes. Table 2 illustrates the volume criteria, where the GEH statistic met the acceptable threshold (< 5) for the intersection at Randol Mill Road and Collins Street.

Table 2: GEH Evaluation of Randol mill Rd & Collins St

VISSIM Volume Counts Data												
Time	Northbound			Southbound			Eastbound			Westbound		
	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT
4:45-5:00	159	35	38	230	26	15	35	27	38	70	28	44
5:00-5:15	224	54	24	297	21	13	41	35	28	88	46	59
5:15-5:30	215	32	35	295	35	16	44	22	26	83	42	38
5:30-5:45	224	26	20	258	35	15	42	20	30	102	43	49
TOTAL	822	147	117	1080	117	59	162	104	122	343	159	190
GEH	2.17	1.21	0.37	3.31	0.00	1.25	1.89	0.48	0.89	0.93	0.08	1.41

For both northbound and southbound directions across all three sections of the corridor where simulation data was collected, speeds remained within the acceptable range of 25 to 35 mph. The speed calibration met the required standards and was successfully validated, as presented in Table 3.

Table 3: Speed comparison across three segments of the corridor

Location	Northbound (mph)		Southbound (mph)	
	Average Speed (ARTH)	Average Speed (Harmonic)	Average Speed (ARTH)	Average Speed (Harmonic)
Start	28.37	27.53	30.16	28.48
Middle	27.89	26.51	27.48	25.72
End	28.99	27.79	27.55	25.33
Average	28.41	27.28	28.40	26.51

Travel time calibration was conducted by comparing Google Maps data with CV data to ensure the model met the required threshold. Using a ground truth of 7 minutes, the acceptable travel time range was set between 360 and 480 seconds. Throughout all 15-minute intervals during the peak hour, the simulated travel times fell within this range. The detailed comparison is shown in Table 4.

Table 4: Travel time calibration results for Collins Street

Time Interval	Travel time(sec)	Min threshold (Sec)	Max threshold (Sec)	Validation
4:45-5:00	419.32	360	480	Met
5:00-5:15	401.91	360	480	Met
5:15-5:30	436.83	360	480	Met
5:30-5:45	413.13	360	480	Met

To replicate conditions during large, planned events, traffic volumes were increased to reflect higher demand. Some intersections saw volume surges of up to 200%, while most experienced at least a 100% increase. For demonstration purposes, the volume changes at the Randol Mill intersection are illustrated in Figure 6.

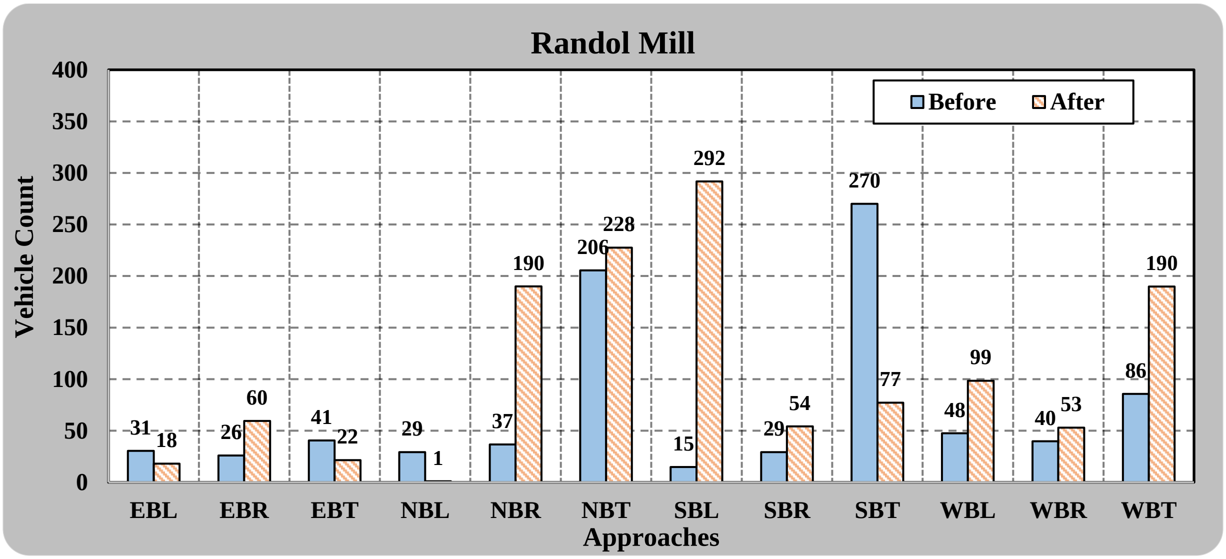

Figure 6: Before-and-after volume analysis at the Randol Mill intersection during event conditions

The team also compared the Level of Service (LOS) at three intersections—Randol Mill, Division Street, and Abram Street—before and after the simulated event scenario. In all cases, the average LOS deteriorated, with two of the intersections reaching LOS E. This comparison is illustrated in Figure 7.

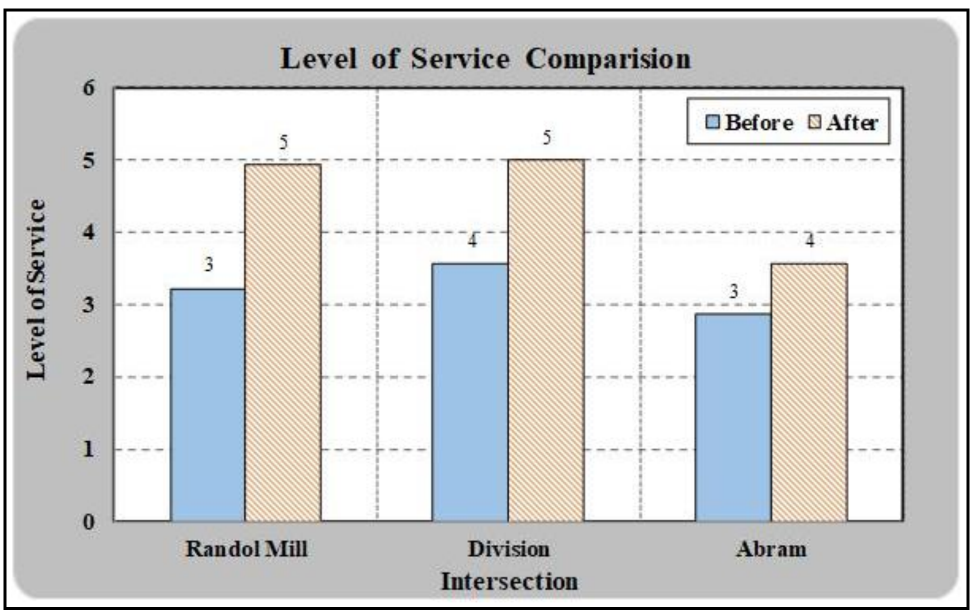

Figure 7: LOS comparison across multiple intersections under increased traffic demand

Once calibration was complete, a comparison between real-world and simulated traffic conditions was conducted for demonstration. The video recording of the scenario with the increased volume has been uploaded to YouTube and can be viewed via this link.

Link to the video: https://www.youtube.com/watch?v=lN9q0Dzq1l0

One such example is the intersection near AT&T Stadium, illustrated in Figure 8.

Figure 8: Comparison of the digital twin simulation and real-world traffic conditions near the stadium on Collins Street

Although pedestrian analysis was not the focus of this study, the model supports pedestrian integration, as shown in Figure 9.

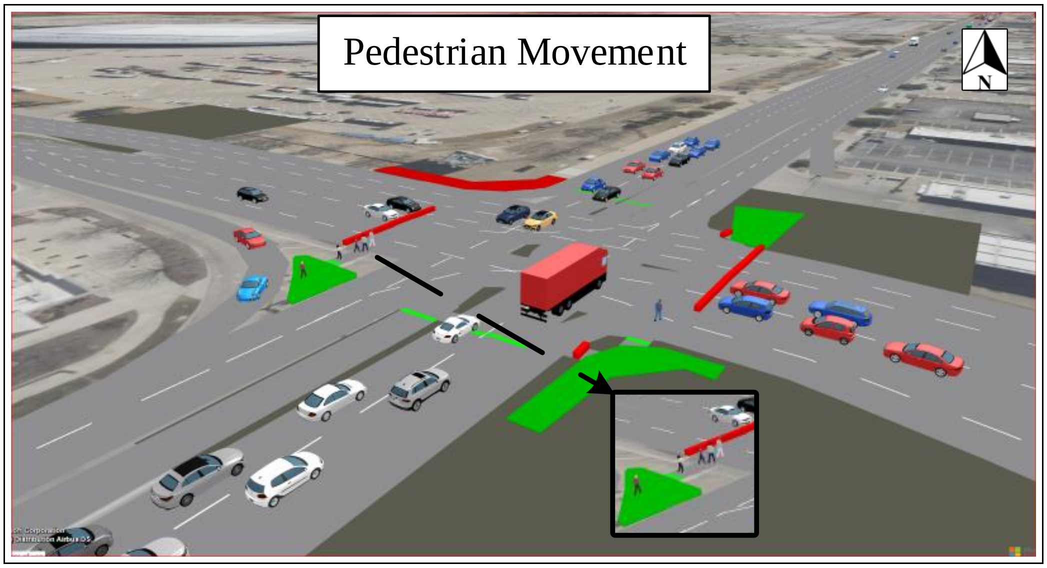

Figure 9: Visualization of pedestrian simulation capability in VISSIM

While this model was developed for a specific use case, it is flexible and can be adapted for other scenarios such as Transit Signal Priority (TSP) and emergency vehicle preemption. Given the proximity of a freight rail line to the stadium, the rail network was also incorporated, as demonstrated in Figure 10.

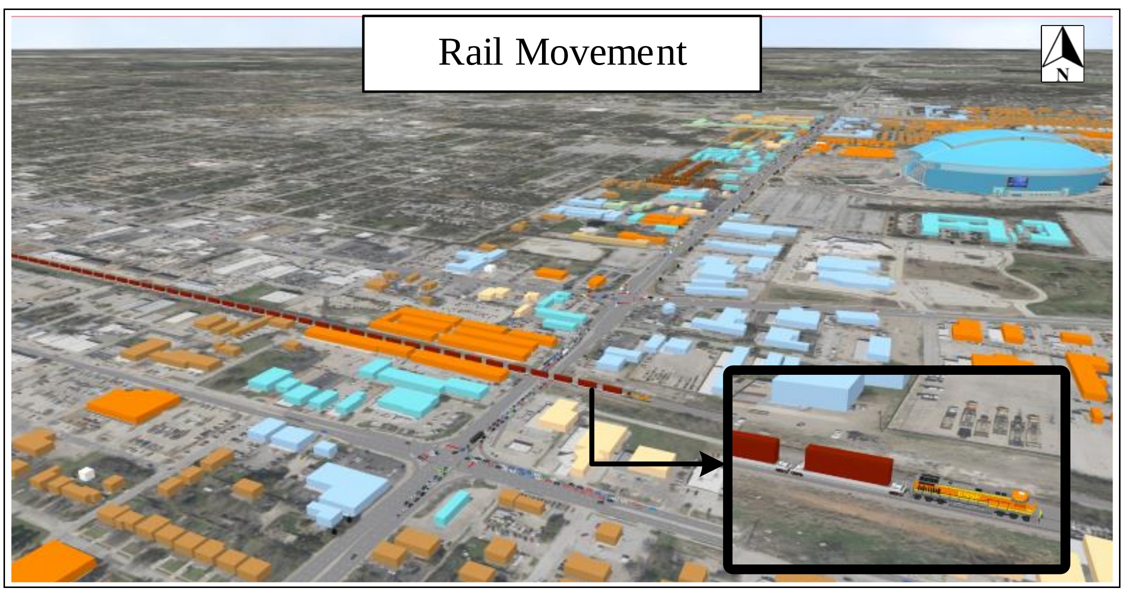

Figure 10: Simulation of railroad preemption functionality in VISSIM

A driver's perspective view is included for comparison in Figure 11.

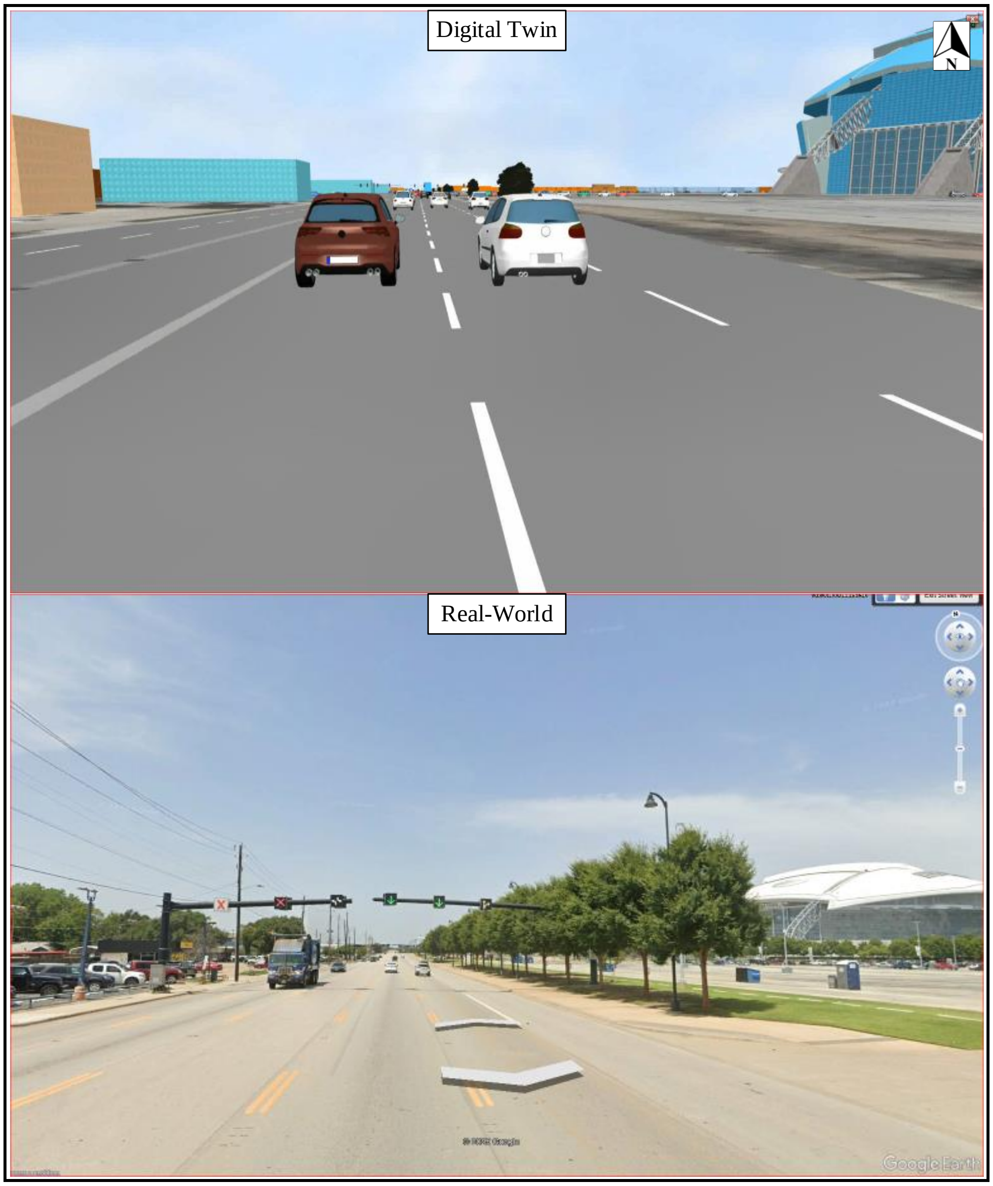

Figure 11: Driver's perspective comparison within the VISSIM environment

To demonstrate that the controller operated with two distinct patterns, a special inbound traffic signal design tailored for event conditions was assigned to Pattern 2. After one hour of simulation, Pattern 2 was activated, indicating the implementation of the inbound signal timing, as illustrated in Figure 12.

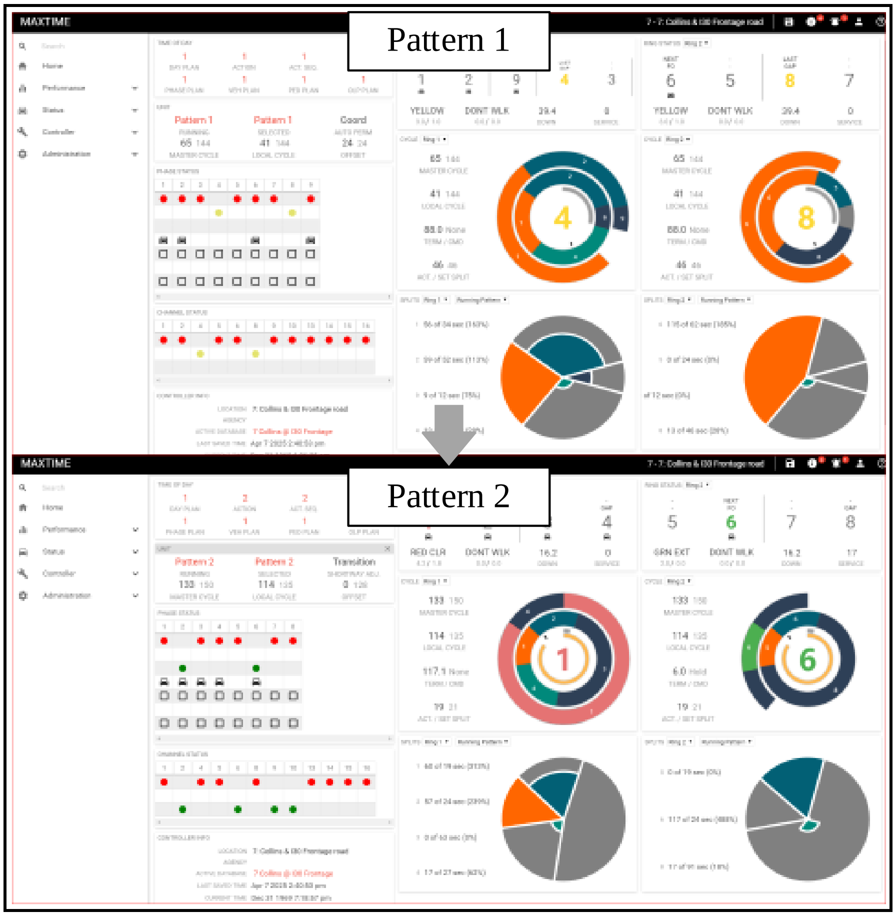

Figure 12: MaxTime controller demonstration showing pattern change before and after activation